Characterization of Aerosols and Atmospheric Parameters from Space-borne and Surface-based Remote Sensing

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LONG-TERM GOAL

The long-term goal for this project is threefold: (i) to develop remote sensing procedures for determining aerosol loading and optical properties over land and ocean, (ii) to use these properties for atmospheric corrections over coastal regions, and (iii) to assess what combination of hyperspectral information can lead to the best results.

OBJECTIVES

In preparation for the era of hyperspectral sensors in remote sensing, we need to establish a climatology of aerosol properties and of spectral reflectance for land, ocean and coastal regions. These specific features will be used to develop aerosol remote sensing capability and in the future corrections of remote sensing data.

APPROACH

During FY98, we have pursued two projects on studying dust aerosols off the coast of Africa: one is the remote sensing of dust over land, and the other is the use of ground-based and space-borne instruments to characterize the dust properties. Although the Landsat TM has limited spectral capability between 0.47 and 2.1 µm, we plan to apply similar techniques to the hyperspectral AVIRIS data. These data were acquired over smoke regions in Brazil and urban pollution in the US, which were collocated with *in situ* and ground-based measurements. The application is expected to show rich spectral characteristics and possible improvement of the technique due to added-value of hyperspectral information. In addition, we plan to compile existing measurements of spectral reflectance in the coastal regions (e.g., collaboration with Drs. Curtiss O. Davis and Bo-Cai Gao at the Naval Research Laboratory in analyzing hyperspectral measurements of ocean reflectance from navy ships) and to conduct airborne hyperspectral measurements (with NASA/Ames instrument) of ocean reflectance and marine aerosols, in support of ONR DUCK campaign (North Carolina, February-March 1999).

WORK COMPLETED

The method for remote sensing of smoke or sulfates over vegetated (dark) regions by Kaufman *et al*. (1997) is extended to include dust over the desert (bright surface). Now, this method can derive aerosol properties in the blue (0.4-0.5 µm) and the red (0.6-0.7 µm) spectral regions. A paper was submit-

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ted to *IEEE-TGARS* on this subject. We also found that the absorption of solar radiation by dust, as expressed by the single scattering albedo, is very different from those documented in the open literature. We have developed a technique, using both satellite spectral data and ground-based observations, to derive the dust particle size, single scattering albedo, and range of the refractive index. A paper was submitted to *Nature* on this subject.

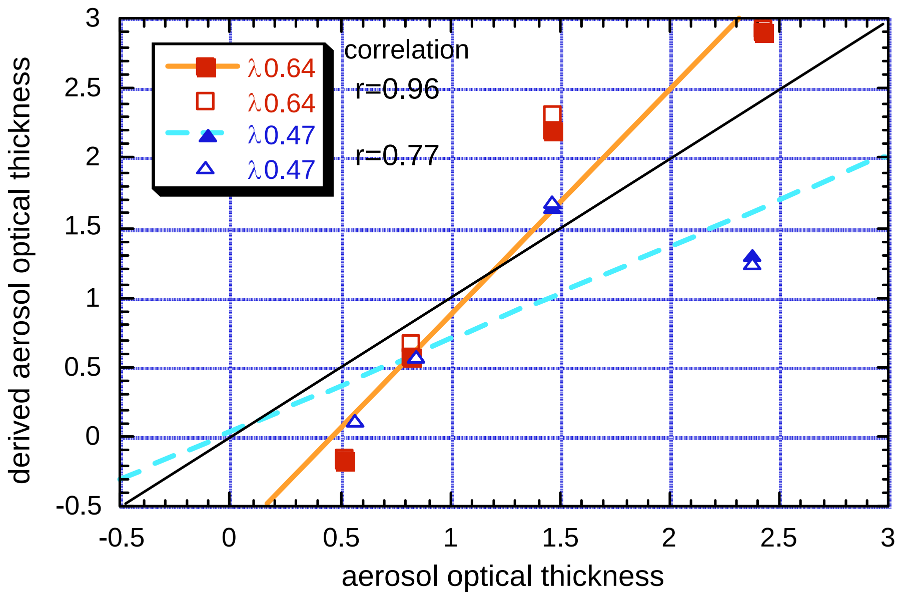

Figure 1: Scatter plot of the derived dust optical thickness and the optical thickness measured by the sunphotometer for the 0.64 µm and 0.47 µm Landsat TM spectral channels. The correlation's are given for each spectral bands. The full symbols are for the average apparent reflectance derived from Landsat data in the vicinity of the sunphotometer and the open symbols for one standard deviation above the average.

RESULTS

We use an approach similar to remote sensing of aerosol over vegetated regions (e.g., a combination of visible and SWIR solar channels) to detect dust over the desert. Analysis of Landsat TM images over Senegal taken in 1987 shows that the surface reflectance at 0.64 µm is 0.54±0.05 of the reflectance at 2.1 µm, and reflectance at 0.47 µm is 0.26±0.03 of that at 2.1 µm. This relationship is surprisingly similar to those in non-desert sites. We also found that dusts have only small effects on the surface-atmosphere reflectance at 2.1 µm over the desert. Therefore, in the presence of dust, we use the Landsat TM data at 2.1 µm channel to predict the surface reflectance at 0.64 and 0.47 µm. The difference between the satellite measured reflectance of surface-atmosphere and the predicted surface reflectance is used to derive the dust optical thickness at 0.64 and 0.47 µm. Results show that the optical thickness can be derived within • • =±0.5 for the range of 0<• <2.5 (*cf*. Fig. 1), thus enabling estimates of dust opacity over the desert. The method is very sensitive to the correct knowledge of the dust absorption, and is equally sensitive to dust loading in the entire atmospheric column. It is best applied in the red (~ 0.64 µm) spectral region where dust was found to be nonabsorbing.

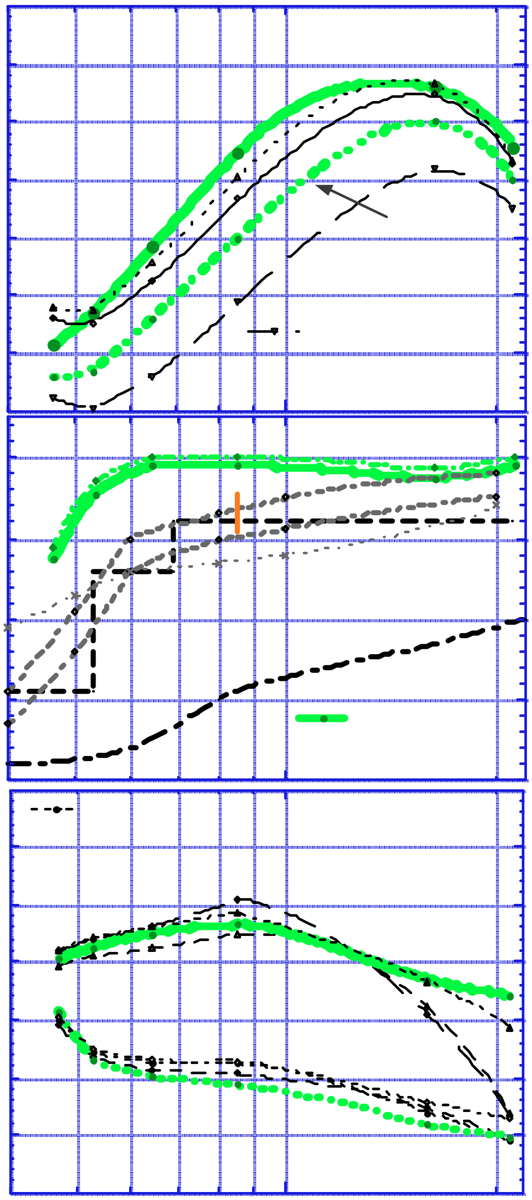

Figure 2: Remote sensing of the dust absorption using Landsat data and ground-based sunphotometer measurements. (A) Apparent reflectance at the top of the atmosphere over the desert measured by Landsat TM (heavy gray lines) for optical thickness of 0.8 (dashed) and 2.4 (solid). The measurements are compared with calculations (thin black lines) for refractive indices and effective radius given in the caption. The apparent reflectance increased due to the presence of dust by ~• • =0.06 (for the central spectral range of 0.55-1.6 µm), despite the high surface reflectance of 0.2 to 0.4. Calculations for imaginary index of -0.004 cannot explain this change in the apparent reflectance, indicating small or no absorption.

(B) The spectral single scattering albedo, • $_o$, for the two values of the effective radius, that fits well with the changes in the apparent reflectance in Fig. 2A (• $_o$=1 - non-absorbing dust and • $_o$=0 - fully absorbing), as compared to • $_o$ values derived or used in the open literature.

(C) Apparent reflectance, as in Fig. 2A but over the ocean, for the absorption indicated in Fig. 2B and several values of real refractive index and effective radius. The real part of the refractive index is kept constant or decreasing to 1.22 at 2.1 µm. This figure shows a good closure for • <1 µm and, in turn, the refractive index of 1.22 at 2 µm is not realistic (~1.46 should be used instead).

Spectral observations of dust properties from the space and from the ground create a powerful tool for determining the absorption of solar radiation by dust with an unprecedented accuracy. Absorption is a key component in understanding the impact of dust on remote sensing and climate, mainly over the Atlantic Ocean. We use Landsat data at 0.47 to 2.1 µm over Senegal with ground-based sunphotometer measurements to find that the absorption of solar radiation by Saharan dust is two to four times smaller

than those documented in the open literature. Although dust absorbs in the blue, almost no absorption was found for wavelengths longer than 0.6 µm (*cf*. Fig. 2). Large scale application of this method to satellite data from the Earth Observing System can reduce significantly the uncertainty in the dust radiative properties, remote sensing from space and correction to derive the ocean properties.

IMPACT

Revisiting the dust models and generating remote sensing procedures of dust over land are the first step for an attempt for hyperspectral remote sensing of coastal regions, as well as correction for the dust effect in these regions to derive the properties of the water and underwater surfaces.

TRANSITIONS

The lower dust absorption may make it possible to distinguish from remote sensing between dust and chlorophyll absorption, and to develop methods to distinguish between the two using hyperspectral remote sensing. The next stage is to compare the spectral signal from dust and other aerosol types and the signal from chlorophyll. We plan to look into data sets already acquired by the Navy of the hyperspectral properties of different waters.

RELATED PROJECTS

This work is related to the NASA/MODIS effort of remote sensing of aerosol and their effect on climate.

PUBLICATIONS

Kaufman, Y. J., A. Karnieli and D. Tanré, 1998: Detection of dust over the desert by EOS-MODIS. submitted to *IEEE-TGARS*.

Kaufman, Y. J., D. Tanré, A. Karnieli, and L. A. Remer, 1998: Dust absorption and radiative forcing derived from measured solar radiation. submitted to *Nature*.

REFERENCES

Kaufman, Y. J. , D. Tanré, L. Remer, E. Vermote, A. Chu, and B. N. Holben, Remote sensing of tropospheric aerosol from EOS-MODIS over the land using dark targets and dynamic aerosol models, *JGR-Atmosphere*, special issue on *Remote Sensing of Aerosol and Atmospheric Corrections*, ***102***, 17051-17067, 1997.